

7.0 Audible Noise

7.1 Basic Concepts

Audible noise (AN), as defined here, represents an unwanted sound, as from a transmission line, transformer, airport, or vehicle traffic. Sound is a pressure wave caused by a sound source vibrating or displacing air. The ear converts the pressure fluctuations into auditory sensations. AN from a source is superimposed on the background or ambient noise that is present before the source is introduced.

The amplitude of a sound wave is the incremental pressure resulting from sound above atmospheric pressure. The sound-pressure level is the fundamental measure of AN; it is generally measured on a logarithmic scale with respect to a reference pressure. The sound-pressure level (SPL) in decibels (dB) is given by:

$$\text{SPL} = 20 \log (P/P_0)\text{dB}$$

where P is the effective rms (root-mean-square) sound pressure, P_0 is the reference pressure, and the logarithm (\log) is to the base 10. The reference pressure for measurements concerned with hearing is usually taken as 20 micropascals (Pa), which is the approximate threshold of hearing for the human ear. A logarithmic scale is used to encompass the wide range of sound levels present in the environment. The range of human hearing is from 0 dB up to about 140 dB, a ratio of 10 million in pressure (EPA, 1978).

Logarithmic scales, such as the decibel scale, are not directly additive: to combine decibel levels, the dB values must be converted back to their respective equivalent pressure values, the total rms pressure level found, and the dB value of the total recalculated. For example, adding two sounds of equal level on the dB scale results in a 3 dB increase in sound level. Such an increase in sound pressure level of 3 dB, which corresponds to a doubling of the energy in the sound wave, is barely discernible by the human ear. It requires an increase of about 10 dB in SPL to produce a subjective doubling of sound level for humans. The upper range of hearing for humans (140 dB) corresponds to a sharply painful response (EPA, 1978).

Humans respond to sounds in the frequency range of 16 to 20,000 Hz. The human response depends on frequency, with the most sensitive range roughly between 2000 and 4000 Hz. The frequency-dependent sensitivity is reflected in various weighting scales for measuring audible noise. The A-weighted scale weights the various frequency components of a noise in approximately the same way that the human ear responds. This scale is generally used to measure and describe levels of environmental sounds such as those from vehicles or occupational sources. The A-weighted scale is also used to characterize transmission-line noise. Sound levels measured on the A-scale are expressed in units of dB(A) or dBA.

AN levels and, in particular, corona-generated audible noise (see below) vary in time. In order to account for fluctuating sound levels, statistical descriptors have been developed for environmental noise. Exceedence levels (L levels) refer to the A-weighted sound level that is exceeded for a specified percentage of the time. Thus, the L_5 level refers to the noise level that is exceeded only 5% of the time. L_{50} refers to the sound level exceeded 50% of the time. Sound-level measurements and predictions for transmission lines are often expressed in terms of exceedence levels, with the L_5 level representing the maximum level and the L_{50} level representing a median level.

Table 6 shows AN levels from various common sources. Clearly, there is wide variation. Noise exposure depends on how much time an individual spends in different locations. Outdoor noise generally does not contribute to indoor levels (EPA, 1974). Activities in a building or residence generally

dominate interior AN levels. The amount of sound attenuation (reduction) provided by buildings is given in Table 7. Assuming that residences along the line route fall in the "warm climate, windows open" category, the typical sound attenuation provided by a house is about 12 dBA.

The BPA design criterion for corona-generated audible noise (L_{50} , foul weather) is 50 ± 2 dBA at the edge of the ROW (Perry, 1982). The Washington Administrative Code provides noise limitations by class of property, residential, commercial or industrial (Washington, State of, 1975). Transmission lines are classified as industrial and may cause a maximum permissible noise level of 60 dBA to intrude into residential property. During nighttime hours (10:00 p.m. to 7:00 a.m.), the maximum permissible limit for noise from industrial to residential areas is reduced to 50 dBA. This latter level applies to transmission lines that operate continuously. The state of Washington Department of Ecology accepts the 50 dBA level at the edge of the right-of-way for transmission lines, but encouraged BPA to design lines with lower audible noise levels (WDOE, 1981).

The EPA has established a guideline of 55 dBA for the annual average day-night level (L_{dn}) in outdoor areas (EPA, 1978). In computing this value, a 10 dB correction (penalty) is added to night-time noise between the hours of 10 p.m. and 7 a.m.

7.2 Transmission-line Audible Noise

Corona is the partial electrical breakdown of the insulating properties of air around the conductors of a transmission line. In a small volume near the surface of the conductors, energy and heat are dissipated. Part of this energy is in the form of small local pressure changes that result in audible noise. Corona-generated audible noise can be characterized as a hissing, crackling sound that, under certain conditions, is accompanied by a 120-Hz hum. Corona-generated audible noise is of concern primarily for con-temporary lines operating at voltages of 345 kV and higher during foul weather. The proposed 500-kV line will produce some noise under foul weather conditions.

The conductors of high-voltage transmission lines are designed to be corona-free under ideal conditions. However, protrusions on the conductor surface—particularly water droplets on or dripping off the conductors—cause electric fields near the conductor surface to exceed corona onset levels, and corona occurs. Therefore, audible noise from transmission lines is generally a foul-weather (wet-conductor) phenomenon. Wet conductors can occur during periods of rain, fog, snow, or icing. Based on meteorologic records near the route of the proposed transmission line, such conditions are expected to occur about 15% of the time during the year in the Spokane area and less at the western end of the proposed corridor.

For a few months after line construction, residual grease or oil on the conductors can cause water to bead up on the surface. This results in more corona sources and slightly higher levels of audible noise and electromagnetic interference if the line is energized. However, the new conductors "age" in a few months, and the level of corona activity decreases to the predicted equilibrium value. During fair weather, insects and dust on the conductor can also serve as sources of corona. The proposed line has been designed with three 1.3-inch (3.30-cm) diameter conductors per phase, which will yield acceptable corona levels. The use of three 1.602-inch (4.07) diameter conductors per phase in Configurations 5, 7, and 9 would reduce AN levels below what they would be with the smaller 1.3-inch conductors.

7.3 Predicted Audible Noise Levels

Audible-noise levels are calculated for average voltage and average conductor heights for fair- and foul-weather conditions. The predicted levels of corona-generated audible noise for the proposed line

operated at a voltage of 540 kV are given in Table 8 and plotted in Figure 4 for the proposed configurations. For comparison, Table 8 also gives the calculated levels for the existing parallel lines.

The calculated median level (L_{50}) during foul weather at the edge of the proposed Grand Coulee – Bell 500-kV line right-of-way with no parallel lines (75 ft. from centerline) is 49 dBA; the calculated maximum level (L_5) during foul weather at the edge of the right-of-way is 52 dBA. These levels are comparable with levels at the edges of some existing 500-kV lines in Washington and slightly lower than the levels from the existing Grand Coulee – Hanford 500-kV line in the Configuration 1 corridor. (See Table 8.) At the edge of the right-of-way adjacent to the existing 500-kV line in Configuration 1, the foul weather L_{50} AN level would change by an indiscernible 1 dBA with the addition of the proposed line. Thus, AN levels for Configurations 1 and 2 would be comparable to those for existing 500-kV lines in Washington.

For Configurations 3 to 9 with multiple parallel lines, the foul weather L_{50} AN level at the edge of the right-of-way would be 42 to 49 dBA. For these configurations, AN from the proposed 500-kV line during foul weather would add +3 to +10 dBA to existing levels at the edges of the right-of-way. The response to such increases would range from barely perceptible to a perceived doubling of the sound level. The AN level increase for a double-circuit configuration would be slightly more (+1 - 2 dBA) than for a single-circuit configurations at the same location. For Configuration 10, which abuts commercial property, the edge-of-right-of-way AN levels would be 51 and 48 dBA at the north and south edges of the right-of-way, respectively.

During fair-weather conditions, which occur about 85% of the time in the Spokane area, audible noise levels at the edge of the right-of-way would be about 20 dBA lower than the foul weather levels (if corona were present). These lower levels could be masked by ambient noise on and off the right-of-way.

7.4 Discussion

The calculated foul-weather corona noise levels for the proposed line with no parallel lines would be comparable to, or less than, those from existing 500-kV lines in Washington. During fair weather, noise from the conductors might be perceivable on the right-of-way; however, beyond the right-of-way it would likely be masked or so low as not to be perceived. During foul weather, when ambient noise is higher, it is also likely that noise off the right-of-way would be masked to some extent. Where the proposed line is located in the center of a corridor with multiple existing lines, the increase of 10 dBA or less due to the addition of the 500-kV line would be perceived as at most a doubling of AN level at the edge of the right-of-way and beyond.

No transformers are being added to the existing Grand Coulee and Bell substations. Noise from the existing substation equipment and transmission lines would remain the primary source of environmental noise at these locations. The large-diameter tubular conductors in the station do not generate corona noise during fair weather; any noise generated during foul weather would be masked by noise from the transmission lines entering and leaving the station. During foul weather, the noise from the proposed and existing lines would mask the substation noise at the outer edges of the rights-of-way.

Off the right-of-way, the levels of audible noise from the proposed line during foul weather would be below the 55-dBA level that can produce interference with speech outdoors. Since residential buildings provide significant sound attenuation (-12 dBA with windows open; -24 dBA with windows closed), the noise levels off the right-of-way would be well below the 45 dBA level required for interference with speech indoors and below the 35 dBA level where sleep interference can occur (EPA, 1973; EPA, 1978). Since corona is a foul-weather phenomenon, people tend to be inside with windows possibly closed,

providing additional attenuation when corona noise is present. In addition, ambient noise levels can be high during such periods (due to rain hitting foliage or buildings), and can mask corona noise.

The 49-dBA level for the proposed line would meet the BPA design criterion and, hence, the Washington Administrative Code limits for transmission lines.

The computed annual L_{dn} level for transmission lines operating in areas with about 15% foul weather is about $L_{dn} = L_{50} - 1$ dBA (Bracken, 1987). Therefore, assuming such conditions in the area of the proposed Grand Coulee – Bell 500-kV line, the estimated L_{dn} at the edge of the right-of-way would be approximately 42 to 50 dBA, which is below the EPA L_{dn} guideline of 55 dBA.

7.5 Conclusion

Along the proposed line route where no parallel lines are present, there would be increases in the perceived noise above ambient levels during foul weather at the edges of the right-of-way. Where the proposed line parallels an existing 500-kV line (Configuration 1), the incremental noise contributed by the proposed line would be less than 5 dBA at the edge of the proposed new right-of-way and beyond, and would barely be discernible from existing noise levels. Where the proposed line is located in the center of the existing Grand Coulee – Bell multi-line corridor, changes in AN at the edges of the right-of-way would be perceived as a doubling or less of the existing sound levels.

The corona-generated noise during foul weather would be masked to some extent by naturally occurring sounds such as wind and rain on foliage. During fair weather, the noise off the right-of-way from the proposed line would probably not be detectable above ambient levels. The noise levels from the proposed line would be below levels identified as causing interference with speech or sleep. The audible noise from the transmission line would be below EPA guideline levels and would meet the BPA design criterion that complies with the Washington state noise regulations.

8.0 Electromagnetic Interference

8.1 Basic Concepts

Corona on transmission-line conductors can also generate electromagnetic noise in the frequency bands used for radio and television signals. The noise can cause radio and television interference (RI and TVI). In certain circumstances, corona-generated electromagnetic interference (EMI) can also affect communications systems and other sensitive receivers. Interference with electromagnetic signals by corona-generated noise is generally associated with lines operating at voltages of 345 kV or higher. This is especially true of interference with television signals. The bundle of three 1.3-inch (or 1.602-inch) diameter conductors used in the design of the proposed 500-kV line would mitigate corona generation and thus keep radio and television interference levels at acceptable levels.

Spark gaps on distribution lines and on low-voltage wood-pole transmission lines are a more common source of RI/TVI than is corona from high-voltage electrical systems. This gap-type interference is primarily a fair-weather phenomenon caused by loose hardware and wires. The proposed transmission line would be constructed with modern hardware that eliminates such problems and therefore minimizes gap noise. Consequently, this source of EMI is not anticipated for the proposed line.

No state has limits for either RI or TVI. In the United States, electromagnetic interference from power transmission systems is governed by the Federal Communications Commission (FCC) Rules and